Estimating Population-level Consequences to Humpback Whales Under Different Levels of Cruise Ship Entry Quotas

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Across the National Park Service, managers struggle with decisions regarding levels of allowable visitation. The NPS mandates that superintendents and other resource managers prohibit activities, including those by concessionaires, that will 'significantly impact' or 'impair' park resources. Yet, depending upon the resource of interest, this can be a difficult standard to follow. In many cases, the dynamics of ecological processes, population numbers, or community structure can be so naturally variable that linking a visitor's activity to changes in a population may not be ascertained with any certainty until impairment has already occurred. Even when national standards defining impairment already exist, such as for air and water quality, the decision may be somewhat ambiguous. For example, a number of streams in Glacier Bay would exceed the Environmental Protection Agency's standards for impairment based on the metric of suspended particulate matter even though these streams are silt laden due only to the natural process of de-glaciation.

Despite the ambiguity in the definition of impairment and its proper application, few managers would argue that an action resulting in a decrease in the natural trajectory of a population of an endangered species constitutes 'significant impact' and therefore be prohibited. Thus, a fundamental question related to humpback whales and cruise ship entry quotas is: How will increases in cruise ship quotas affect the population dynamics of endangered humpback whales in Glacier Bay based on what we currently know about ship-whale interactions?

In order to answer this question, we used a model of whale population dynamics forecasted to 2028 under different levels of cruise ship traffic. The model required us to specify the mechanism by which cruise ships could alter population dynamics of humpback whales, and then an estimate of how this process would change if ship entries increase. As several authors have described in accompanying articles, the two most direct mechanisms by which cruise ships impact humpback whales is via acoustical disturbance or severe injury or death as a result of collisions. Acoustical impacts likely occur on a daily basis, as most whales in Glacier Bay and surrounding waters hear the ships from many miles away. Less clear is how many, or to what degree, whales alter their behavior in response to the noise generated from cruise ships. Isolating the effects of cruise ship-generated noise on changes in habitat use or movements to other areas will be difficult owing to factors such as changes in fish abundance and distribution, which affect whale movements and behavior on a daily and seasonal basis. As a result, relating these levels of acoustical exposure to some population level metric, such as lowered survival rate or changes in reproduction, is particularly difficult. In contrast, collisions between cruise ships and whales have a more direct link to fitness (survival) because, given the size and speed of the ships, it is likely that any direct collision will result in a severe injury or death to the whale. Thus, we focused only on the relationship between ship entries and probability of collision to estimate how changes in ship quotas may significantly impact the population dynamics of humpback whales using Glacier Bay and surrounding waters.

To do so we needed to estimate four things. First, we needed to know how many whales are using (status) and have used (trend) Glacier Bay in order to forecast future population levels. Second, we needed to estimate the level of 'mixing' among areas in Southeast Alaska. For example, humpback whales in Alaska generally migrate to Hawaii

Figure 1. An endangered humpback whale dives near Glacier Bay National Park and Preserve. Individual humpback whales have been photographically identified since the 1970s under a long term monitoring program in and around the park. Working in collaboration with researchers from the University of Alaska Southeast, Sitka Campus and others, sighting of over 1,500 whales have been compiled in southeastern Alaska, forming the basis of the mark-recapture population abundance estimates used for population simulations presented here. Details of the mark-recapture study will be submitted for peer-reviewed scientific publication in late 2010 (*Hendrix et al. in prep*). For more information on life history studies of these long-lived whales, see http://www.alaskahumpbacks.org

NPS photograph

Glacier Bay - 2028				
Ship-Whale Collision Detection Probablity	100%	100%	10%	10%
Cruise Ship Entries to GLBA	139	184	139	184
Abundance	2098 (149, 5219)	2097 (149, 5219)	2065 (192, 5315)	2073 (189, 5217)
Trend	5.49% (-7.4%, 10.1%)	5.49% (-7.42%, 10.1%)	5.46% (-6.00%, 10.1%)	5.44% (-6.06%, 10.1%)
Additional Collisions		1.07 (0.3)		10.6 (5.17)
Additional Loss of Whales		1.53 (0.00, 6.46)		15.2 (3.79, 35.71)

Figure 2. Projected estimates of abundance and trend of humpback whales in 2028 under different ship-whale collision detection levels (10% detected vs. 100% detected) and peak season quotas of 139 ship entries (2004 levels) vs. 184 entries (maximum allowable under the Glacier Bay Vessel Quota and Operating Requirements EIS). Additional collisions indicate the number of ship-whale collisions accrued over 20 years should the NPS allow for 184 vs. 139 entries per year. Additional loss of whales represents the loss to the population as a result of death from collision plus the productivity attributed to those whales had they been able to live and reproduce, for entries of 184 vs. 139. Parenthesis indicate the lower and upper levels of a 95% probability interval around the median.

each year for reproductive activities, returning to Alaska in early spring. Individuals may spend all summer in Glacier Bay, migrate to Hawaii, and then return to spend all summer in another area of Alaska, such as Sitka Sound or Frederick Sound. Or, they may move among areas in Alaska during the summer. This annual level of 'fidelity' to an area is important to know. If little migration occurs to/from areas in Alaska any incidental mortality (such as from an increase in collisions with cruise ships), will affect the whales in that location only. If whales commonly migrate among areas, the population can buffer the incidental mortality via migration of other adults into the park.

Third, we needed to estimate the annual survival rate of whales using Glacier Bay. The annual survival rate will incorporate all sources of mortality, including natural causes of death such as from predation, or anthropogenic sources of mortality, such as entanglements with fishing gear, to generate an estimate of the probability that an adult will survive from one year to the next. This estimate forms the base survival rate upon which any additional mortality, such as more whale deaths as a result of permitting higher numbers of cruise ships into the dense population of whales using Glacier Bay, would lower the base survival rate. Fourth and final, we needed to estimate the rate at which whales are struck by ships under existing entry quotas.

To generate quantitative estimates of abundance, fidelity, and survival, we used a modified 'mark-recapture' model, using a long-term photographic monitoring data set. Researchers from Glacier Bay, the University of Alaska Sitka, and several other institutions have, for many years, photographed the flukes of humpback whales in Glacier Bay and several other aggregation hotspots to identify individuals and track their movements (*Figure 1*). This data set has been used to generate abundance and trend estimates previously (*Straley et al. 2009*), and we updated these estimates under a probability-based framework which allows explicit incorporation of uncertainty.

We also estimated the rate of collisions between cruise ships and whales. Based on 1 known collision that occurred in 2001, another (assumed) collision in 2004, and 1694 entries of cruise ships over the period of 2001 to 2009, we estimated the rate of collisions as 0.00118 (collisions per ship entry). However, this estimate is low because not all collisions are detected. Thus, we further modeled the probability of detecting a collision given that one occurred. If we assume that all struck whales are detected, i.e., 100% detection probability, then the rate of collisions is 0.00118. However, if only 10% of the actual collisions are detected, then the rate of collisions is 0.0118. The assumption of a 10% detection rate likely overestimates the number of whales struck (20 between 2001 and 2009) but provides a worst case scenario on the impacts to the population.

Our results from the model simulating population dynamics under different levels of cruise ships and detection probability are summarized in Figure 2. The

results demonstrate that even under the most conservative assumptions and after explicitly incorporating uncertainty, increasing the number of cruise ships to Glacier Bay will not significantly impact the population dynamics of humpback whales. For example, assuming only 10% of struck whales are detected, the median trend estimate under the maximum number of ship entries (184 per year, for 20 years) differs only slightly from our median trend estimate under conditions of 139 entries and 100% detection probability. This result is due to the low rate of collisions relative to the current increasing population trend (which in turn is due to a high survival rate and high reproductive rate).

So, should Glacier Bay allow increases in cruise ship traffic? It is important to consider the limitations of this modeling exercise. Our effort focused only on the role of collisions between ships and whales and did not include the suite of mechanisms by which ships can impact humpback whales, including acoustical disturbance. It is also possible that the trend of Glacier Bay may change over the next 20 years, which may not support the current rate of growth for this population. Continued support of the whale monitoring program will be important in order to quantify and track these changes. However, the population of humpback whales is robust. At its current rate and assuming no other conditions change, an increase in ship traffic will not likely significantly impact or impair the population of whales using Glacier Bay. Park managers will need to consider the benefits of visitation with the potential loss of whales, even if the population dynamics are not likely to change.

NPS photograph

Figure 3. Breaching may be one form of communication among humpback whales.

REFERENCES

Straley, J.M., T.J. Quinn II, and C.M. Gabriele. 2009.
Assessment of mark-recapture models to estimate the abundance of a humpback whale feeding aggregation in southeast Alaska. Journal of Biogeography 36: 427-438.